CLAIMS

1. A lithographic projection apparatus comprising:

a support structure configured to support a patterning structure, the patterning structure being configured to pattern a beam of radiation according to a desired pattern;

a substrate table configured to hold a substrate including an alignment structure having spatially periodically varying optical properties; and

an alignment system configured to obtain positional information from light affected by the substrate, to determine a position of the alignment structure relative to the patterning structure based on the positional information, and to control a relative positioning of the patterning structure and the substrate based on the determined position,

wherein the alignment system is further configured to obtain position-invariant information from light affected by the substrate and to determine, based on the position-invariant information, a correction to a determination of a position of an alignment structure of at least one among (1) the substrate, (2) another substrate that has been subjected to a processing operation in common with the substrate, and (3) a further substrate that has been subjected to a further processing operation according to the same value of a processing parameter used to subject the substrate to the further processing operation.

2. The lithographic projection apparatus according to Claim 1, wherein the alignment system is configured to measure a phase value of light diffracted by the alignment structure and to determine the position of the alignment structure based on the phase value.

3. The lithographic projection apparatus according to Claim 1, wherein the alignment system is arranged to measure intensities of individual pairs of diffraction orders of light diffracted by the alignment structure.

4. The lithographic projection apparatus according to Claim 3, wherein the alignment system is arranged to measure a phase value for at least one pair of diffraction orders, the correction being based on the phase value and the measured intensities.

5. The lithographic projection apparatus according to Claim 3, wherein the alignment system includes a model describing at least one position-dependent optical effect of the alignment structure, and

wherein the alignment system is arranged to compute information about a distance between (1) the measured intensities and (2) corresponding values based on the model and to estimate at least one value of the position based on a parameter of the model that minimizes the distance.

6. The lithographic projection apparatus according to Claim 3, wherein the alignment system includes a model describing at least one position-dependent optical effect of the alignment structure, and

wherein the alignment system is arranged to estimate a value of a parameter of the model that corresponds to at least one of the measured intensities and to determine the correction based on the estimated value.

7. The lithographic projection apparatus according to Claim 6, wherein the alignment system is arranged to compute information about a distance between the measured intensities and values of the intensities according to the model and to determine the at least one estimated value so as to minimize the distance.

8. The lithographic projection apparatus according to Claim 6, wherein the alignment system includes a set of available parameters of the model, and

wherein the alignment system comprises an interface configured to permit selection of at least one parameter from the set of available parameters, the correction being based on an estimated value of the at least one selected parameter.

9. The lithographic projection apparatus according to Claim 8, wherein the alignment system is configured to determine the correction independent of a parameter of the set of available parameters that is not selected.

10. The lithographic projection apparatus according to Claim 6, wherein the parameter of the model describes a geometrical property of the alignment structure.

11. The lithographic projection apparatus according to Claim 1, wherein the alignment system includes a phase grating alignment system.

12. The lithographic projection apparatus according to Claim 1, wherein the alignment system is arranged to measure position-invariant information from light of a plurality of wavelengths, and

wherein the correction is based on the position-invariant information from light of a plurality of wavelengths.

13. The lithographic projection apparatus according to claim 1, said apparatus further comprising a neural network configured to determine the correction.

14. A lithographic projection apparatus comprising:

a support structure configured to hold a patterning structure, the patterning structure being configured to pattern a beam of radiation according to a desired pattern;

a substrate table configured to hold a substrate having an alignment structure; and

an alignment system configured to measure properties of light affected by the alignment structure, to determine a position of the alignment structure relative to the patterning structure based on the measured properties, and to control a relative positioning of the patterning structure and the substrate based on the determined position,

wherein the alignment system includes a model describing physical properties of the alignment structure, and

wherein the alignment system is arranged to estimate a value of a parameter of the model that corresponds to at least one of the measured properties and to determine a correction to the determined position based on the estimated value.

15. The lithographic projection apparatus according to Claim 14, wherein the alignment system is arranged to compute information about a distance between the measured properties and values of the properties according to the model and to determine the at least one estimated value so as to minimize the distance.

16. The lithographic projection apparatus according to Claim 14, wherein the alignment system includes a set of available parameters of the model, and

wherein the alignment system comprises an interface configured to permit selection of at least one parameter from the set of available parameters, the correction being based on an estimated value of the at least one selected parameter.

17. The lithographic projection apparatus according to Claim 14, wherein the parameter of the model describes geometrical properties of the alignment structure.

18. A device manufacturing method comprising:

using a patterning structure to pattern a beam of radiation according to a desired pattern;

determining a position, relative to the patterning structure, of an alignment structure having spatially periodically variable optical properties, based on positional information from light affected by a substrate having the alignment structure; and

controlling a relative positioning of the patterning structure and the substrate, based on the position;

wherein said determining a position includes obtaining position-invariant information from the light affected by the substrate and determining, based on the position-invariant information, a correction to a determination of a position of an alignment structure of at least one among (1) the substrate, (2) another substrate that has been subjected to a processing operation in common with the substrate, and (3) a further

substrate that has been subjected to a further processing operation according to the same value of a processing parameter used to subject the substrate to the further processing operation.

19. The device manufacturing method according to Claim 18, wherein said determining a position includes measuring a phase value of light diffracted by the alignment structure and determining the position of the alignment structure based on the phase value.

20. The device manufacturing method according to Claim 18, wherein said determining a position includes measuring intensities of individual pairs of diffraction orders of light diffracted by the alignment structure.

21. The device manufacturing method according to Claim 20, wherein said determining a correction includes measuring a phase value for at least one pair of diffraction orders, the correction being based on the phase value and the measured intensities.

22. The device manufacturing method according to Claim 20, wherein said determining a correction includes applying a model describing at least one position-dependent optical effect of the alignment structure, computing information about a distance between (1) the measured intensities and (2) corresponding values based on the model, and estimating at least one value of the position based on a parameter of the model that minimizes the distance.

23. The device manufacturing method according to Claim 20, wherein said determining a correction includes applying a model describing at least one position-dependent optical effect of the alignment structure, and

wherein said applying a model includes estimating a value of a parameter of the model that corresponds to at least one of the measured intensities, and

wherein the correction is based on the estimated value.

24. The device manufacturing method according to Claim 23, wherein said applying the model includes computing information about a distance between the measured intensities and values of the intensities according to the model and determining the at least one estimated value so as to minimize the distance.

25. The device manufacturing method according to Claim 23, wherein said determining a correction includes selecting at least one parameter from among a set of available parameters of the model, the correction being based on an estimated value of the at least one selected parameter.

26. The device manufacturing method according to Claim 25, wherein said determining a correction is performed independently of a parameter of the set of available parameters that is not selected.

27. The device manufacturing method according to Claim 23, wherein the parameter of the model describes a geometrical property of the alignment structure.

28. The device manufacturing method according to Claim 18, wherein said obtaining position-invariant information includes measuring position-invariant information from light of a plurality of wavelengths, and

wherein the correction is based on the position-invariant information from light of a plurality of wavelengths.

29. The device manufacturing method according to Claim 18, wherein said determining a correction includes using a neural network.

30. A device manufacturing method comprising:

using a patterning structure to pattern a beam of radiation according to a desired pattern;

measuring properties of light affected by the alignment structure;

determining a position of the alignment structure relative to the patterning structure based on the measured properties;

controlling a relative positioning of the patterning structure and the substrate, based on the determined position;

wherein said determining a position includes applying a model describing physical properties of the alignment structure, estimating a value of a parameter of the model that corresponds to at least one of the measured properties, and determining a correction to the determined position based on the estimated value.

31. The device manufacturing method according to Claim 30, wherein said applying the model includes computing information about a distance between the measured properties and values of the properties according to the model and determining the estimated value so as to minimize the distance.

32. The device manufacturing method according to Claim 30, wherein said determining a correction includes selecting at least one parameter from among a set of available parameters of the model, wherein the set is based on the nature of processing steps to which the substrate has been subjected.

33. The device manufacturing method according to Claim 30, wherein the parameter of the model describes a geometrical property of the alignment structure.

34. The device manufacturing method according to Claim 30, wherein said determining a position includes using the estimated value to select an initial value in a search for at least one further parameter,

wherein the method further comprises using the at least one further parameter to determine a position of at least one of (1) a further alignment structure on said substrate and (2) an alignment structure on a further substrate.